PHOTOMETRIC MONITORING OF FOLIAGE LOSS FROM A WIND STORM, ISLAND OF HAWAI'I

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The non-seasonal, non-cyclical occurrence of certain natural events such as high-wind storms, makes the monitoring of their effects on vegetation difficult. It is fortuitous that the author had photographed 180 'ōhi'a (Metrosideros polymorpha Gaud.) trees three weeks before a severe storm struck the Hawaiian Islands in January 1980. The trees were photographed again a few days after the storm, and by comparing the two sets of photographs, foliage loss and other crown damage is readily apparent.

The original photographs were part of a sequence of photographs taken to monitor the effects of fertilization and stand thinning on 'ōhi'a trees in areas of incipient dieback (Mueller-Dombois 1977). This photometric monitoring is designed specifically to measure the loss or increase of canopy foliage in individual trees. Thus, the photographs are well-suited to observing foliage loss from the windstorm.

MATERIALS AND METHODS

Study Area

The field experiment briefly described above was repeated at three sites in montane rain forest on the island of Hawai'i. The data reported in this paper are from one of the three sites which is located six-tenths of a mile ENE of Thurston Lava Tube, Hawaii Volcanoes National Park, at an elevation of 3920 feet. In the original experimental design, 60 'ōhi'a canopy trees were selected for treatment and monitoring at this site. Trees with partially defoliated crowns were chosen. The 60 trees were divided into four treatment groups. The treatments applied were fertilization, stand thinning, combined thinning and fertilization, and no treatment. For this report, dealing with wind damage to canopy trees, the four treatment groups are not considered separately.

Photographic Methods

The 60 subject trees were photographed on 18 December 1979 and on 14 January 1980. (The storm was reported by the National Weather Service from 7 to 12 January). The photographs were taken through a 50 mm lens with a 35 mm single lens reflex camera. Kodak Plus-X film (ASA 125) was used in December; Kodak Tri-X film (ASA 400) was used in January and has been used subsequently. Exposures were determined automatically by the camera's internal light meter and exposure system. Frames were intentionally over-exposed if the overhead sky contained clouds which were highly reflective. The film was processed in Microdol-X developer and prints were made on Kodak Polycontrast Rapid RC paper using Dektol Developer. All negatives were printed with the same enlargement factor.

Photographs were taken from the ground, as near to the trunk of the subject tree as practicable. The camera was pointed up, vertically or nearly vertically, with the crown of the subject tree centered in the viewfinder. To ensure the repeated photographing of each tree from the same angle, a marker peg was driven into the ground near each tree. The photographs were taken holding the camera above the peg at eye level while standing in a normal manner.

The pairs of photographs of each tree were analyzed for foliage loss by measuring the area of the crown or a portion of the crown of the subject tree with a dot grid (Mueller-Dombois & Ellenberg 1974). Identifiable positions on the photgraphs, such as forked branches, were used as reference points to ensure placement of the grid on identical portions of the two images of each tree.

Climatic Data

The National Weather Service at General Lyman Field, Hilo, Hawai'i, reported a severe storm on the days of 7 to 12 January 1980. The most severe weather occurred on 8, 9, and 10 January. The average daily wind speeds at General Lyman Field for those three days were 17.3; 7.5; and 4.9 mph, respectively. The same parameter for 28 non-storm days in January averaged 5.8 mph. The maximum sustained one-minute wind speed for each of those three days was 25, 18, and 17 mph and for 28 non-storm days the average was 11.7 mph.

Recording instruments at the weather observatory on Mauna Loa, Hawai'i, at an elevation of 11,000 feet, recorded average hourly wind speeds of 31, 44, and 51 mph for 8, 9, and 10 January, respectively. The averaged hourly average for 23 non-storm days in January was 12.1 mph. The wind speed at the observatory was estimated to have reached 100 mph (National Weather Service).

Anemometers at Hawaii Volcanoes National Park are not recording instruments but give instantaneous read-outs only. Gusts of 75 knots were measured during the storm, and wind speeds of over 60 knots were observed on 8, 9, and 10 January (Ralph Klein, pers. comm.). The National Park Service (NPS) measurements were taken a few miles from the Thurston Lava Tube study site.

RESULTS

Tree crown area was measured with a dot grid on 37 pairs of photographs taken before and after the storm. The change (Δ) and percent change ($\%\Delta$) of crown area between the two photographs of each tree were calculated. The data are shown in Table 1.

The photographic pairs of the other 23 subject trees were judged unsuitable for analysis for technical reasons, usually because the two photographs were not taken from the identical angle and, therefore, the images were not comparable.

The mean of the percent change in crown area from December to January is a negative (decrease) 12.3; standard error of the mean is 1.25; and standard deviation is 7.60. A 99% confidence interval (Sokal & Rohlf 1969) of ± 3.22 can be constructed around the mean. As can be seen in Table 1, two trees showed a slight gain in crown area, one tree had no change.

DISCUSSION

Canopy photography is used in forestry research to measure vegetation and environmental paramenters. The "fish-eye" lens (a 180°, wide-angle lens) has been used widely, especially for studying the radiation climate (Evans & Coombe 1959; Anderson 1964, 1971). Brown and Worley (1965) describe the use of fish-eye photography to estimate areal canopy coverage. "Areal coverage" is defined as "percent of sky covered by canopy as viewed from a point at or near the ground."

For the 'ōhi'a forest study described in this paper, wide-angle or fish-eye photography was considered but rejected. The experimental subject is the individual tree, not the forest canopy. A standard 50 mm lens yields much greater detail when photographing only the portion of the canopy near the zenith. The objective of this technique is to monitor exact crown segments for repeated measurements. The technique does not yield a crown cover estimate (*sensu* Mueller-Dombois & Ellenberg 1974) representative of the stand. A measurement of crown interceptions on the photographic image is similar to areal coverage as defined above. By measuring only the area near the zenith, distortion due to deviation from the vertical is small; this measurement approximates the crown cover of that tree's canopy.

Sakasegawa (1975) used a 35 mm camera with a 50 mm lens for photographing the canopy in a variety of community types. An opaque mask with a transparent circle 23 mm in diameter was placed over the 35 mm negative to define the portion of the canopy within 15° of the zenith. The percent of the negative, within the circle, covered by foliage or other plant parts was measured with an optical data integration system (Wingert 1973; Sakasegawa 1975). Sakasegawa has termed the crown cover within 15° of the zenith "moosehorn-type" cover because of its similarity to the measurements made with the moosehorn crown closure estimator (Garrison 1949).

Since January 1980, some improvements in the photographic technique have been made to ensure that each tree is always photographed from the same angle. A set of photographs is carried into the field now in protective holders. The exact center of each photograph has been marked. Thus, in the field, it is possible to locate on the crown of the subject tree itself, that point corresponding to the central point marked on the photograph. The camera viewfinder should be centered on that point. The camera should then be rotated around the central point until the trunk of the subject tree passes through the lower left corner of the viewfinder, and then the tree crown should be photographed.

Effects of Wind Damage

At this time there is no evidence of effects from the storm other than the physical loss of foliage, branches, and in some case, the overthrowing of living trees. Mueller-Dombois (pers. comm.) has suggested that foliage loss from a storm such as occurred in January 1980, might bring about the death of overmature or nutritionally stressed 'ōhi'a trees. It is hypothesized that such marginal trees may be physiologically near the photosynthesis-respiration compensation point and might not be able to withstand the loss of a large portion of their leaves. In such a case, an entire stand of 'ōhi'a trees, already in a deteriorated physiological condition, might go into a dramatic decline if hit by another stress, such as a wind storm. At this time, there is no new evidence to support this hypothesis.

The ecological effects of foliage loss include an increase of light at the forest floor. This increase of light may stimulate reproduction of certain shade intolerant species such as 'ōhi'a, or it may stimulate the growth of certain undergrowth and groundcover species. Groundcover species that might be advantaged by an increase of light include the exotic grasses *Isachne* sp., *Microlaena stipoides* (Labill.) R. Br., and *Sacciolepis indica* (L.) Chase.

The overthrowing of mature 'ōhi'a trees has not been reported directly in this paper, but general observations around the study site have shown that many trees were knocked down by the January storm. The shallow soils above lava bedrock are partially responsible for this phenomenon. The soil at the Thurston Lava Tube site averages about 24 inches depth. The large gaps created in the canopy by fallen trees may be ecologically important in forests where "gap-phase" reproduction is the norm (Cooray 1974).

CONCLUSION

The photographs of 'ōhi'a tree crowns give direct evidence of foliage loss from the high winds of 8, 9, and 10 January 1980. Substantial loss of foliage during the January storm was detected. The physiological and ecological consequences of the foliage loss are not evident at this time.

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TABLE 1. Number of dots intercepting tree crowns on photographs taken in December 1979 and in January 1980. Change (Δ) in number of interceptions from December to January and percent change (%Δ) are shown. Change is a decrease in crown area unless otherwise indicated.

Tree No.	Dec.	Jan.	Δ	%Δ	Tree No.	Dec.	Jan.	Δ	%Δ
C17	286	222	64	22	F27	338	310	28	8
C18	327	291	36	11	F67	241	204	37	15
C20	273	251	22	8	F68	405	403	2	0
C21	336	323	13	4	F71	173	161	12	7
C25	213	183	30	14	F72	377	346	31	8
C29	526	473	53	10	F77	233	190	43	18
C30	342	330	12	4	F83	410	327	83	20
T2	471	385	86	18	F84	481	455	26	5
T3	211	183	28	13	F85	338	350	+12	+ 4
T5	304	256	48	16	TF32	488	432	56	11
T11	175	128	47	27	TF34	294	239	55	19
T15	354	292	62	18	TF49	699	667	32	5
T28	273	247	26	10	TF50	326	259	67	21
T36	224	155	69	31	TF51	216	201	15	7
T39	327	233	4	1	TF52	444	455	+11	+ 2
T43	336	273	63	19	TF55	379	347	32	8
T44	309	258	51	17	TF58	265	234	31	12
TF59	362	346	16	4	TF64	265	201	64	24
TF66	376	326	51	13					